Magneto-spectroscopy of donor bound excitons in homoepitaxial GaN

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Recent investigations of the near band edge emission in GaN layers show fine structure of the D^0X (exciton bound to neutral donor) band, the origin of which is subject of considerable interest. Our high quality homoepitaxial GaN layers show the D^0X emission band split into several extremely sharp components (linewidths of about 0.1meV). Here we report on the identification of these sharp lines using advantages of the magneto-luminescence and spin-flip Raman scattering experiments.

The measurements have been performed in magnetic fields up 14 T employing different orientations of the magnetic field with respect to the c-axis of GaN crystals. For the B||c configuration, the circular polarisation of the emission has been measured. In the photoluminescence spectra measured at zero magnetic field we distinguish three groups of D^0X transitions, each group associated, correspondingly, with the ground states of excitons A, B and C, as well as the group of transitions involving the first excited state of excitons A and B. Our classification of the D^0X lines results from the analysis of the data obtained in magnetic fields. In particular we conclude that lines grouped in the first series of transitions involve different donor sites, although they are associated with the same exciton A ground state. We concentrate on this first series of transition when demonstrating the data obtained in magnetic fields. As shown in Figs. 1 and 2, this series in the absence of magnetic field is composed of at least six lines.

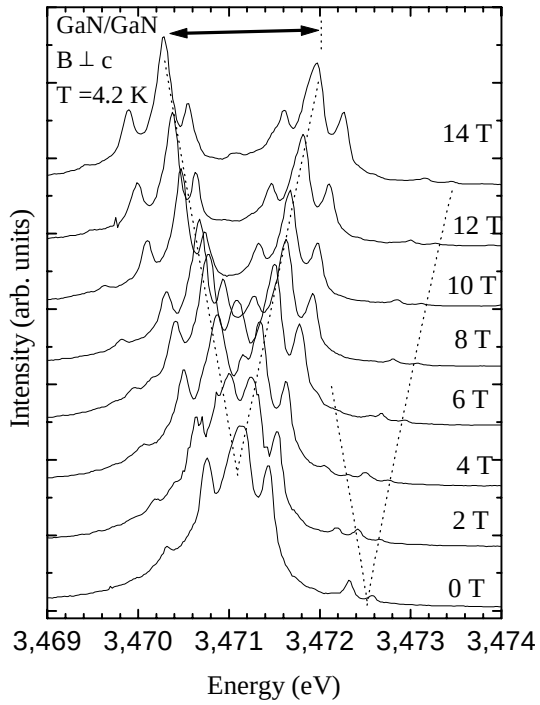

Fig. 1 The evolution of the D^0X emission measured for the B⊥c configuration.

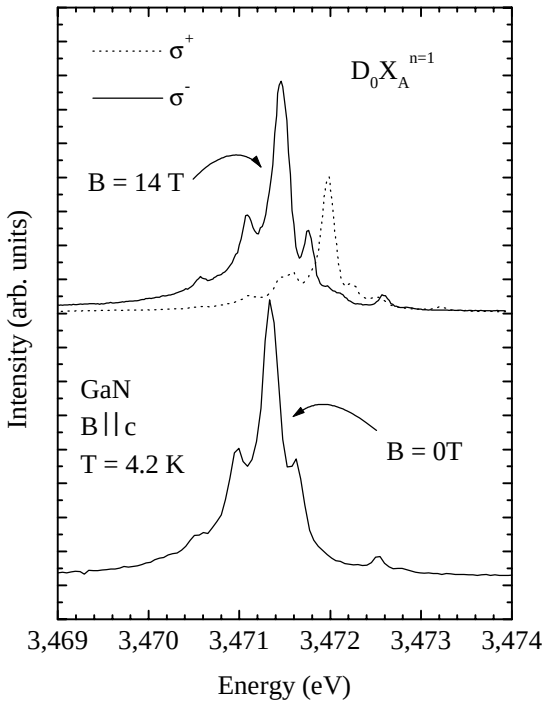

Fig. 2 Polarisation resolved emission due to recombination of excitons bound to neutral donors.

Each of the line splits further into two Zeeman components when the magnetic field is applied. Zeeman doublets are equally intense in case of the B⊥c configuration (Fig.1.), whereas for the B||c configuration (Fig. 2), the low energy (σ^-) component always dominates over the higher energy one. For the case of the B||c configuration, the effective g-factors involve both electronic and valence band contribution to the Zeeman splitting. The measured values are slightly different for different lines and vary between 0.6 and 0.8. On the other hand, the effective g-factor of 2.1 has been found to be common for all six lines in the case of the B⊥c configuration. This latter value should be regarded as the g-factor of an electron involved in the bound exciton recombination. The obtained value of 2.1 is relatively close to the electronic g-factor (1.98) obtained from spin-flip Raman scattering experiments performed on the same samples (Fig.3).

The identification of different donor centres (sites) in our structures is confirmed by the analysis of the emission band related to a two electron replica of the D^0X transitions. This emission band arises from recombination processes of D^0X excitons, characterised by the final state of the neutral donor being in an excited state. In the absence of magnetic field, the emission band of two-electron D^0X transitions is relatively broad. Magnetic field splits this emission band into several components, related to different donor states (Fig. 4). The magnetic field pattern of the excited states of each individual donor can be investigated. Although, the magnetic-field fanchart of the excited states follows roughly the energy ladder of a (renormalized) hydrogen atom in magnetic fields for each donor site, slight differences in the excited states position can be distinguished in dependence of the chemical and/or structural nature of the individual donor states.

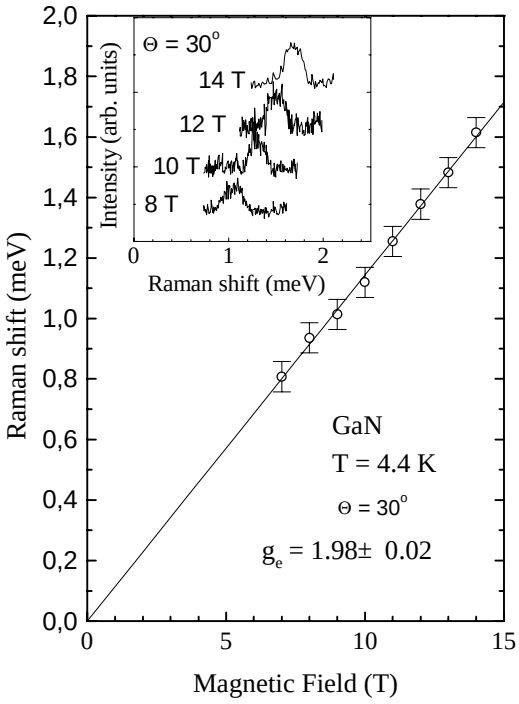

Fig. 3. Magnetic field dependence of the spin-flip Raman scattering transition measured for $\theta = 30^0$. The signal has been found to be insensitive to the field direction and identified with electron spin-flip transitions

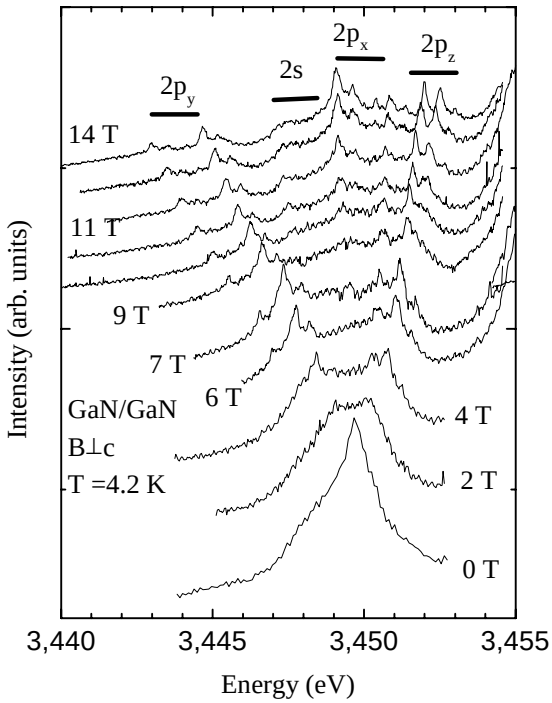

Fig. 4 Magnetic field dependence of the two-electron transitions observed for the B⊥c configuration.

In summary, we believe that applying the advanced magneto-spectroscopy methods we have been able to identify the origin of the fine structure of the D^0X band observed in high quality GaN layers. This fine structure is partially due to presence of different donor centres with different chemical or structural character. Each individual donor centres is characterised by its specific binding energy as well as the characteristic ladder of the excited states which are clearly resolved under the application of the magnetic field.